5

Radioactive Waste

Low-Level Radioactive Waste Disposal

Low-level radioactive waste (LLW) includes items contaminated with radioactive material or exposed to neutron radiation. This waste typically consists of contaminated protective shoe covers and clothing, wiping rags, mops, filters, reactor water treatment residues, equipment and tools, medical waste, and laboratory animal carcasses and tissue.

Some LLW is quite low in radioactivity—even as low as just above background levels found in nature. Some licensees, notably hospitals, store such waste on site until it has decayed and lost most of its radioactivity. Then it can be disposed of as ordinary trash. Other LLW, such as parts of a reactor vessel from a nuclear power plant, is more radioactive and requires special handling. Waste that does not decay fairly quickly is stored until amounts are large enough for shipment to an LLW disposal site in containers approved by DOT and the NRC.

Commercial LLW can be disposed of in facilities licensed by either the NRC or Agreement States. The facilities are designed, constructed, and operated to meet NRC safety standards. The facility operator analyzes how the facility will perform in the future based on the environmental characteristics of the site. Current LLW disposal uses shallow land disposal sites with or without concrete vaults (see Figure 35: Low-Level Waste Disposal).

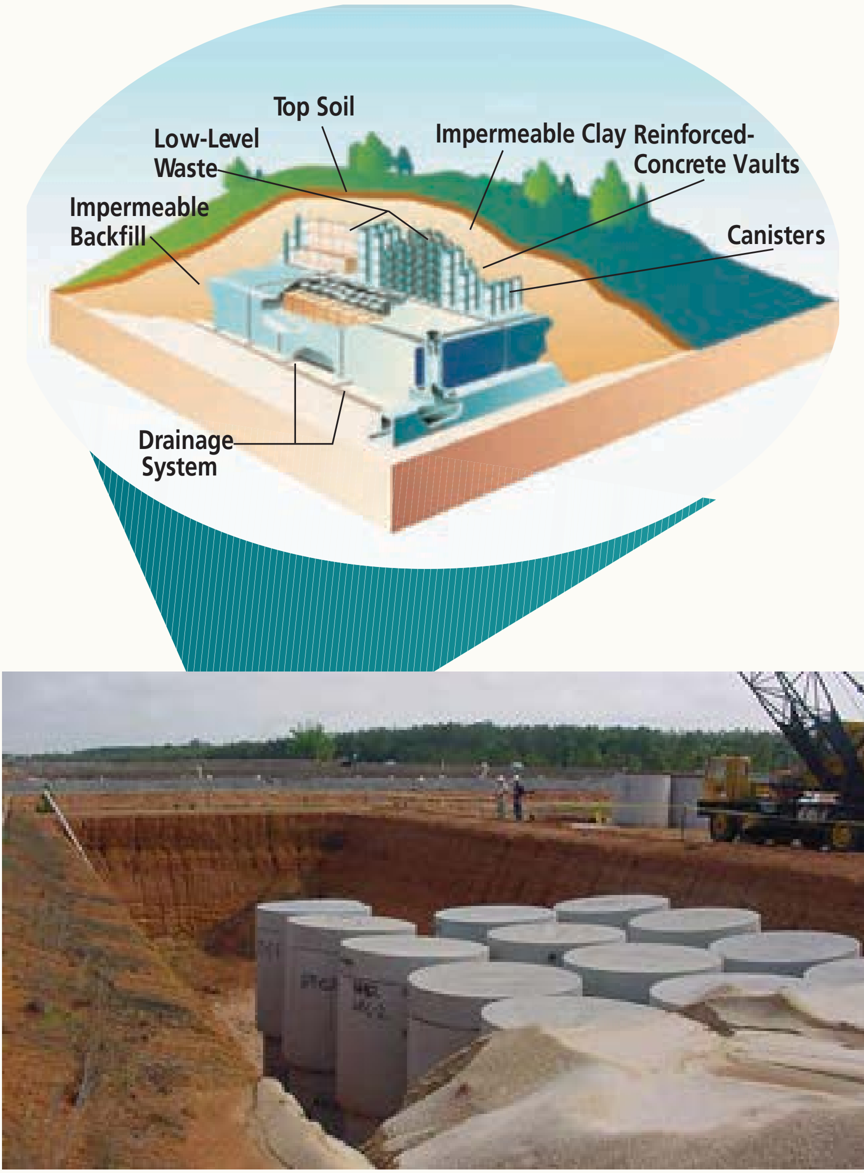
The NRC classifies LLW based on its potential hazards. It has specified disposal and waste requirements for three classes of waste—Classes A, B, and C—with progressively higher concentrations of radioactive material. Class A waste, the least radioactive, accounts for approximately 96 percent of the total volume of LLW. Determination of the classification of waste is a complex process. A fourth class of LLW, called "greater-than-Class-C," is not generally acceptable for near-surface, shallow-depth disposal. By law, DOE is responsible for disposal of greater-than-Class-C waste generated under an NRC license. Although it falls under DOE jurisdiction, it is not high-level waste.

The volume and radioactivity of waste vary from year to year. Waste volumes currently include several million cubic feet each year from reactor facilities undergoing decommissioning and from cleanup of contaminated sites.

The Low-Level Radioactive Waste Policy Amendments Act of 1985 gave the States responsibility for LLW disposal. The Act authorized States to:

- form regional compacts, with each compact to provide for LLW disposal site access
- manage LLW import to, and export from, a compact
- exclude waste generated outside a compact

Figure 35. Low-Level Waste Disposal



This LLW disposal site accepts waste from States participating in a regional disposal agreement.

The States have licensed four active LLW disposal facilities:

- EnergySolutions' Barnwell facility, located in Barnwell, SC—Previously, Barnwell accepted LLW waste from all U.S. generators of LLW. As of July 2008, Barnwell accepts waste only from the Atlantic Compact States of Connecticut, New Jersey, and South Carolina. The State of South Carolina licenses Barnwell to receive Classes A, B, and C waste.
- EnergySolutions' Clive facility, located in Clive, UT—Clive accepts waste from all regions of the United States. The State of Utah licenses Clive for Class A waste only.
- US Ecology's Richland facility, located in Richland, WA, on the Hanford Nuclear Reservation—Richland accepts waste from the Northwest Compact States (Alaska, Hawaii, Idaho, Montana, Oregon, Utah, Washington, and Wyoming) and the Rocky Mountain Compact States (Colorado, Nevada, and New Mexico). The State of Washington licenses Richland to receive Classes A, B, and C waste.
- Waste Control Specialists' Andrews facility, located in Andrews, TX—Andrews accepts waste from the Texas Compact, which consists of Texas and Vermont. It also accepts waste from out-of-the-compact generators on a case-by-case basis. Andrews began receiving waste in 2011. The State of Texas licenses Andrews to receive Classes A, B, and C waste.

See Appendix Q for Regional Compacts and Closed LLW Sites.

Licensees post locations of radioactive areas around the plants to ensure proper radiation protection measures at the facilities.

High-Level Radioactive Waste Management

Spent Nuclear Fuel Storage

Commercial spent nuclear fuel, although highly radioactive, is stored safely and securely in 34 States. This includes 30 States with operating nuclear power reactors, where spent fuel is safely stored on site in spent fuel pools and in dry casks. The remaining four States—Colorado, Idaho, Maine, and Oregon—do not have operating power reactors but are safely storing spent fuel at storage facilities. Waste can be stored safely in pools or casks for 100 years or more. The NRC licenses and regulates the storage of spent fuel, both at commercial nuclear power plants and at separate storage facilities.

Most reactor facilities were not designed to store the full amount of spent fuel that the reactors would generate during their operational lives. Facilities originally planned to store spent fuel temporarily in deep pools of continuously circulating water, which cools the spent fuel assemblies. After a few years, the facilities were expected to send the spent fuel to a reprocessing plant. However, in 1977, the Government declared a moratorium on reprocessing spent fuel in the United States. Although the Government later lifted the restriction, reprocessing has not resumed in the United States.

See Appendices O and P for information about dry spent fuel storage and licensees.

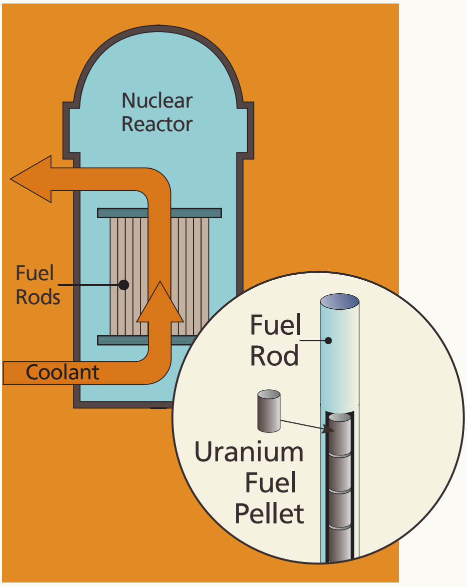
See Glossary for fuel reprocessing (recycling).

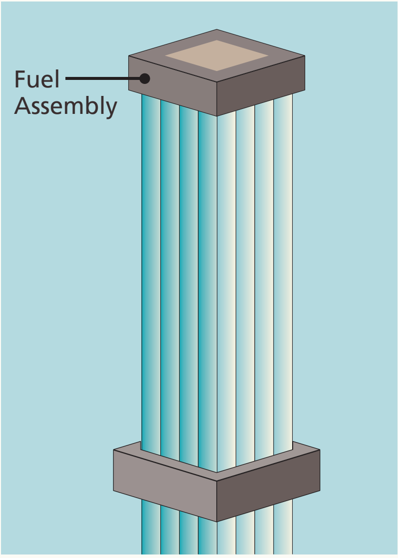
As a result, facilities expanded their storage capacity by using high-density storage racks in their spent fuel pools (see Figure 36: Spent Fuel Generation and Storage after Use). To provide supplemental storage, some fuel assemblies are stored in dry casks on site. These facilities are called independent spent fuel storage installations (ISFSIs) and are licensed by the NRC. These large casks are typically made of leak-tight, welded, and bolted steel and concrete surrounded by another layer of steel or concrete. The spent fuel sits in the center of the cask in an inert gas. Dry cask storage shields people and the environment from radiation and keeps the spent fuel inside dry and nonreactive (see Figure 37: Dry Storage of Spent Nuclear Fuel).

As of June 2015, there were 74 licensed ISFSIs in the United States (see Figure 38: Licensed and Operating Independent Spent Fuel Storage Installations by State). The NRC authorizes storage of spent fuel at an ISFSI by one of two licensing options: site-specific licensing or general licensing.

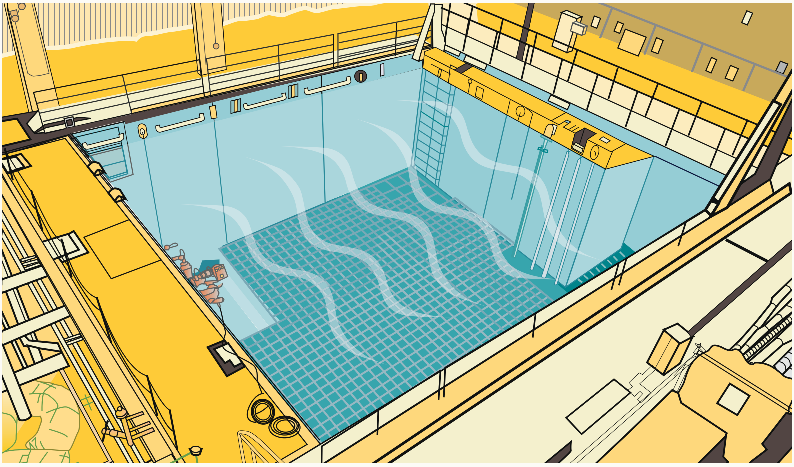
Figure 36. Spent Fuel Generation and Storage After Use

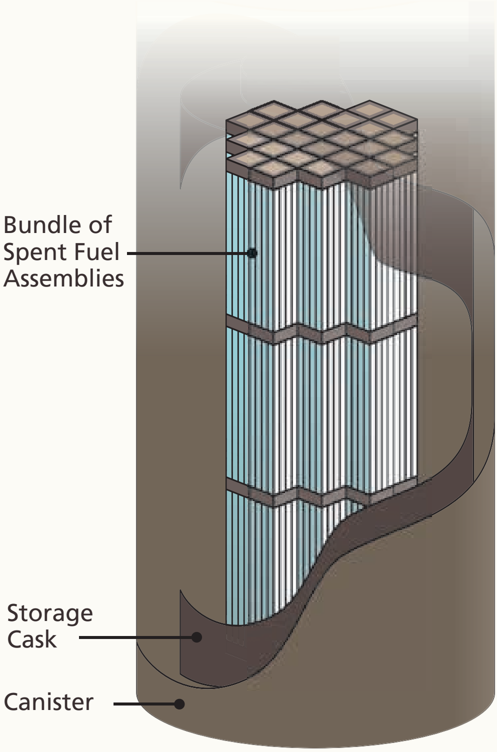
1 A nuclear reactor is powered by enriched uranium-235 fuel. Fission (splitting of atoms) generates heat, which produces steam that turns turbines to produce electricity. A reactor rated at several hundred megawatts may contain 100 or more tons of fuel in the form of bullet-sized pellets loaded into long metal rods that are bundled together into fuel assemblies. Pressurized-water reactors (PWRs) contain between 150 and 200 fuel assemblies. Boiling-water reactors (BWRs) contain between 370 and 800 fuel assemblies.





2 After 5–6 years, spent fuel assemblies—typically 14 feet (4.3 meters) long and containing nearly 200 fuel rods for PWRs and 80–100 fuel rods for BWRs—are removed from the reactor and allowed to cool in storage pools. At this point, the 900-pound (409-kilogram) assemblies contain only about one-fifth the original amount of uranium-235.





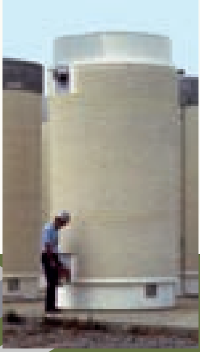
3 Commercial light-water nuclear reactors store spent radioactive fuel in a steel-lined, seismically designed concrete pool under about 40 feet (12.2 meters) of water that provides shielding from radiation. Water pumps supply continuously flowing water to cool the spent fuel. Extra water for the pool is provided by other pumps that can be powered from an onsite emergency diesel generator. Support features, such as water-level monitors and radiation detectors, are also in the pool. Spent fuel is stored in the pool until it is transferred to dry casks on site (as shown in Figure 37) or transported off site for interim storage or disposal.

Figure 37. Dry Storage of Spent Nuclear Fuel

At nuclear reactors across the country, spent fuel is kept on site, typically above ground, in systems basically similar to the ones shown here. The NRC reviews and approves the designs of these spent fuel storage systems before they can be used.

1 Once the spent fuel has sufficiently cooled, it is loaded into special canisters that are designed to hold nuclear fuel assemblies. Water and air are removed. The canister is filled with inert gas, welded shut, and rigorously tested for leaks. It is then placed in a cask for storage or transportation. The dry casks are then loaded onto concrete pads.

2 The canisters can also be stored in aboveground concrete bunkers, each of which is about the size of a one-car garage.



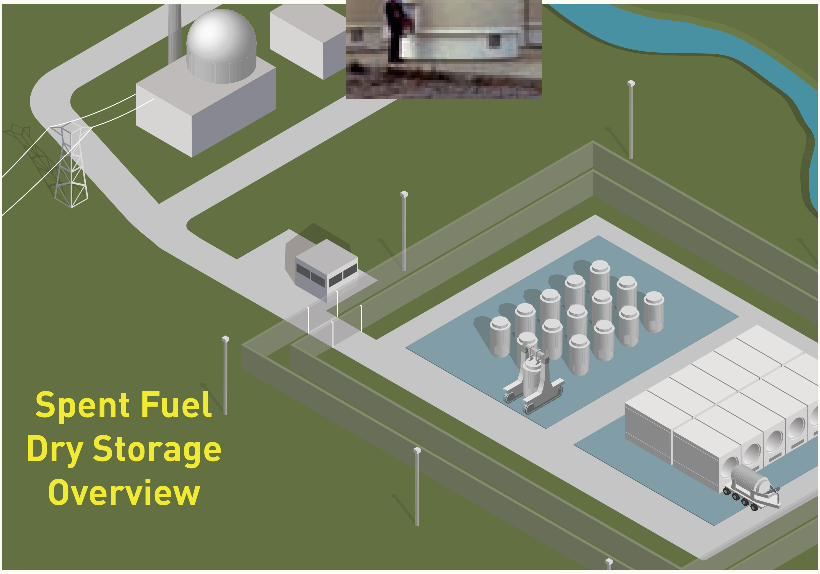
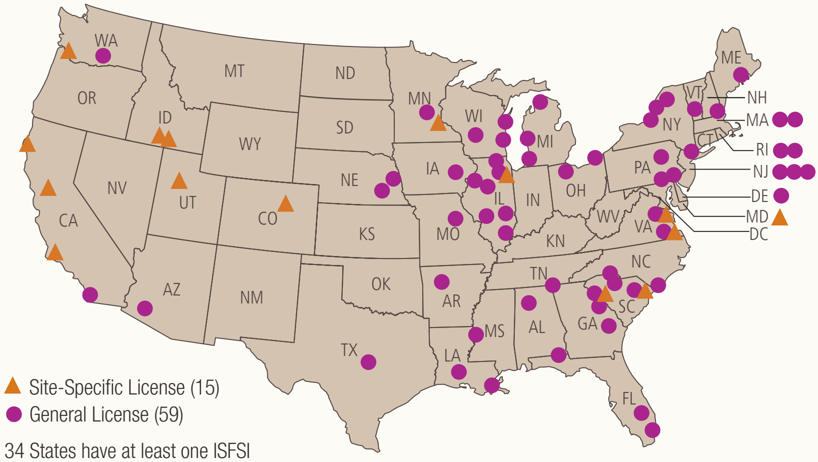


Figure 38. Licensed and Operating Independent Spent Fuel Storage Installations by State



ALABAMA
- ● Browns Ferry
- ● Farley

ARIZONA
- ● Palo Verde

ARKANSAS
- ● Arkansas Nuclear

CALIFORNIA
- ▲ Diablo Canyon
- ▲ Rancho Seco
- ● San Onofre
- ▲ Humboldt Bay

COLORADO
- ▲ Fort St. Vrain

CONNECTICUT
- ● Haddam Neck
- ● Millstone

FLORIDA
- ● St. Lucie
- ● Turkey Point

GEORGIA
- ● Hatch
- ● Vogtle

IDAHO
- ▲ DOE: TMI-2 (Fuel Debris)
- ▲ DOE: Idaho Spent Fuel Facility

Data as of July 2015
NRC-abbreviated site names listed

ILLINOIS
- ● Braidwood
- ● Byron
- ▲ GE Hitachi Morris (Wet)
- ● Dresden
- ● La Salle
- ● Quad Cities
- ● Zion

IOWA
- ● Duane Arnold

LOUISIANA
- ● River Bend
- ● Waterford

MAINE
- ● Maine Yankee

MARYLAND
- ▲ Calvert Cliffs

MASSACHUSETTS
- ● Yankee Rowe
- ● Pilgrim

MICHIGAN
- ● Big Rock Point
- ● Palisades
- ● Cook
- ● Fermi

MINNESOTA
- ● Monticello
- ▲ Prairie Island

MISSISSIPPI
- ● Grand Gulf

MISSOURI
- ● Callaway

NEBRASKA
- ● Cooper
- ● Ft. Calhoun

NEW HAMPSHIRE
- ● Seabrook

NEW JERSEY
- ● Hope Creek
- ● Salem
- ● Oyster Creek

NEW YORK
- ● Indian Point
- ● FitzPatrick
- ● Ginna
- ● Nine Mile Point

NORTH CAROLINA
- ● Brunswick
- ● McGuire

OHIO
- ● Davis-Besse
- ● Perry

OREGON
- ▲ Trojan

PENNSYLVANIA
- ● Limerick
- ● Susquehanna
- ● Peach Bottom
- ● Beaver Valley

SOUTH CAROLINA
- ● ▲ Oconee
- ● ▲ Robinson
- ● Catawba

TENNESSEE
- ● Sequoyah

TEXAS
- ● Comanche Peak

UTAH
- ▲ Private Fuel Storage

VERMONT
- ● Vermont Yankee

VIRGINIA
- ● ▲ Surry
- ● ▲ North Anna

WASHINGTON
- ● Columbia

WISCONSIN
- ● Point Beach
- ● Kewaunee
- ● LaCrosse

The NRC grants site-specific licenses after a safety review of the technical requirements and operating conditions for the ISFSI. The license term can be up to 40 years and can be renewed for up to another 40 years. A general license from the NRC authorizes a nuclear power reactor licensee to store spent fuel on site in dry storage casks. Under the general license, the authority to use a storage cask is tied to the cask's certificate of compliance issued through a rulemaking. The NRC has issued certificates to several dry storage cask designs. The agency issues initial and renewed certificates for terms not to exceed 40 years.

Public Involvement

The public can participate in decisions about spent fuel storage, as it can in many licensing and rulemaking decisions. The Atomic Energy Act of 1954, as amended, and the NRC's own regulations call for public hearings about site-specific licensing actions and allow the public to comment on certificate of compliance rulemakings. Members of the public may also file petitions for rulemaking. Additional information on ISFSIs is available on the NRC's Web site (see the Web Link Index).

Spent Nuclear Fuel Disposal

The current U.S. policy governing permanent disposal of high-level radioactive waste is defined by the Nuclear Waste Policy Act of 1982, as amended, and the Energy Policy Act of 1992. These acts specify that high-level radioactive waste will be disposed of underground in a deep geologic repository.

In the autumn of 2014, the NRC published NUREG-2157, "Generic Environmental Impact Statement for Continued Storage of Spent Nuclear Fuel". This report examined the environmental impacts of storing spent fuel for several decades until a repository is available. Because the timing of repository availability is uncertain, the report looked at potential impacts over three possible timeframes: a short-term timeframe, which includes 60 years of continued storage after the end of a reactor's licensed life for operation; an additional 100-year timeframe (60 years plus 100 years) to address the potential for delay in repository availability; and a third, indefinite timeframe in case a repository never becomes available.

The NRC also implemented a final rule on continued storage that adopts the findings of the generic environmental impact statement into regulation. This rule is important for issuing new or renewed licenses for nuclear power plants and spent fuel storage facilities.

Transportation

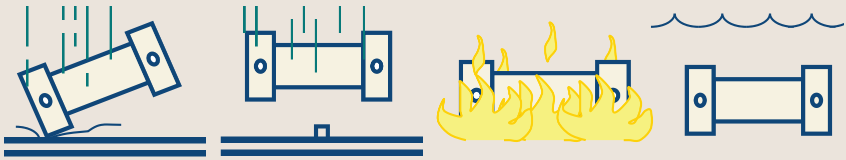
The NRC is also involved in the transportation of spent nuclear fuel. The NRC establishes safety and security requirements in collaboration with DOT, certifies transportation cask designs, and conducts inspections to ensure that requirements are being met.

Spent fuel transportation casks are designed to meet the following safety criteria under both normal and accident conditions:

- prevent the loss or dispersion of radioactive contents
- shield everything outside the cask from the radioactivity of the contents
- dissipate the heat from the contents
- prevent nuclear criticality (a self-sustaining nuclear chain reaction) from occurring inside the cask

Transportation casks must be designed to survive a sequence of tests, including a 30-foot (9-meter) drop onto an unyielding surface, a puncture test, a fully engulfing fire at 1,475 degrees Fahrenheit (802 degrees Celsius) for 30 minutes, and immersion under water. This very severe test sequence, akin to the cask striking a concrete pillar along a highway at high speed and being engulfed in a severe and long-lasting fire, and then falling into a river, simulates conditions more severe than 99 percent of vehicle accidents (see Figure 39: Ensuring Safe Spent Fuel Shipping Containers).

Figure 39. Ensuring Safe Spent Fuel Shipping Containers



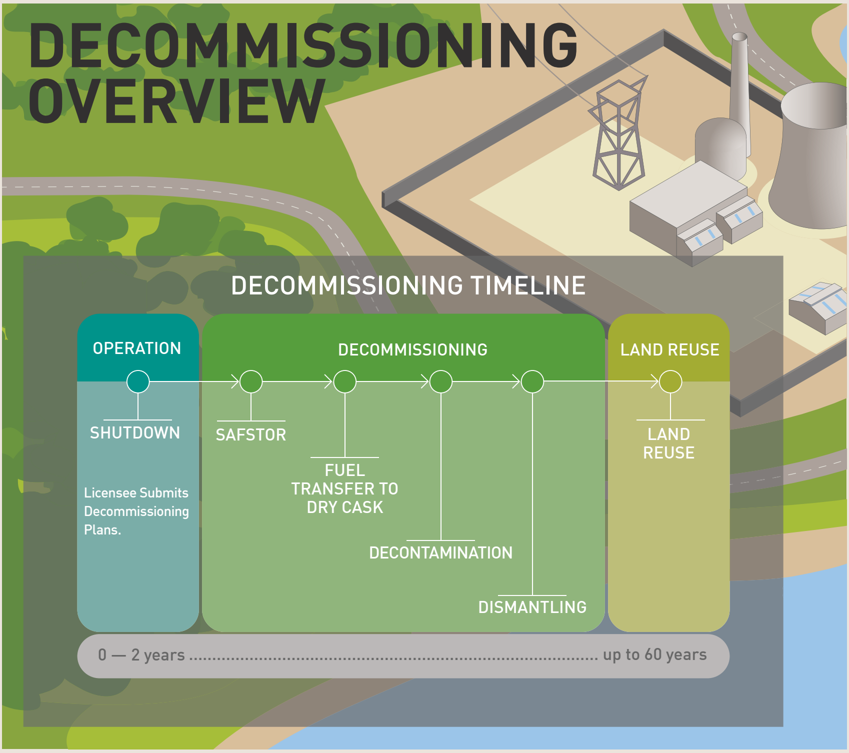
The impact (free drop and puncture), fire, and water immersion tests are considered in sequence to determine their cumulative effects on a given package.

To ensure the safe transportation of spent fuel and other nuclear materials, each year the NRC:

- conducts about 1,000 transportation safety inspections of fuel, reactor, and materials licensees
- reviews, evaluates, and certifies approximately 65 new, renewed, or amended transportation package design applications
- conducts 16 inspections of cask vendors and manufacturers to ensure the quality of dry cask design and fabrication
- reviews and evaluates approximately 150 license applications for the export or import of nuclear materials

Additional information on materials transportation is available on the NRC's Web site (see the Web Link Index).

Figure 40. Decommissioning Overview Timeline



Decommissioning

Decommissioning is the safe removal of a nuclear facility from service and the reduction of residual radioactivity to a level that permits release of the property and termination of the license. NRC rules establish site-release criteria and provide for unrestricted and (under certain conditions) restricted release of a site. The NRC also requires all licensees to maintain financial assurance that funds will be available when needed for decommissioning.

The NRC regulates the decontamination and decommissioning of nuclear power plants, materials and fuel cycle facilities, research and test reactors, and uranium recovery facilities, with the ultimate goal of license termination.

For commercial power reactors that have ceased operations, the decommissioning process may take up to 60 years. This may include extended periods of inactivity (called SAFSTOR), during which residual radioactivity is allowed to decay, making eventual cleanup easier and more efficient. A facility is said to be in “DECON” when active demolition and decontamination is underway. Active decommissioning of a nuclear power plant takes about 10 years on average.

During 2013, the Kewaunee, Crystal River, and San Onofre 2 and 3 nuclear power reactors permanently shut down and entered the decommissioning process. The Vermont Yankee reactor ceased operations at the end of 2014.

The NRC terminates approximately 150 materials licenses each year. Most of these license terminations are routine, and the sites require little or no cleanup to meet the NRC’s criteria for unrestricted access. The decommissioning program focuses on the termination of licenses for sites involving more complex decommissioning activities. (See Figures 40: Decommissioning Overview Timeline, 41: Power Reactors Decommissioning Status, and 42: Locations of NRC-Regulated Sites Undergoing Decommissioning.)

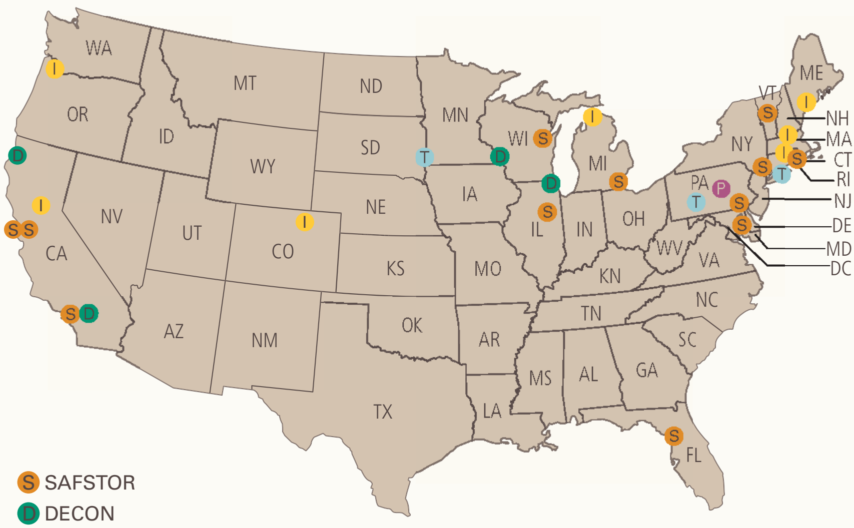
As of June 2015, the following facilities were undergoing decommissioning under NRC jurisdiction (see Figure 43: Facilities Undergoing Decommissioning under NRC Jurisdiction):

- 19 nuclear power and early demonstration reactors
- 15 complex material sites
- five RTRs
- two fuel cycle facilities
- 11 uranium recovery facilities

See Appendices C, K, and R for licensees undergoing decommissioning.

The “Status of the Decommissioning Program 2014 Annual Report” contains additional information on the decommissioning programs of the NRC and Agreement States. More information is on the NRC’s Web site (see the Web Link Index).

Figure 41. Power Reactors Decommissioning Status



S SAFSTOR
D DECON
P PDMS (Post Defueling Monitored Storage)

I ISFSI (Independent Spent Fuel Storage Installation only)
T License Terminated
Decommissioning Completed

CALIFORNIA
- S GE EVESR
- S GE VBWR
- D Humboldt Bay 3
- I Rancho Seco
- S San Onofre 1
- D San Onofre 2 and 3

COLORADO
- I Fort St. Vrain
(DOE License)

CONNECTICUT
- S Millstone 1
- I Haddam Neck

FLORIDA
- S Crystal River 3

ILLINOIS
- S Dresden 1
- D Zion 1 and 2

MARYLAND
- S N.S. Savannah

MASSACHUSETTS
- I Yankee Rowe

MAINE
- I Maine Yankee

MICHIGAN
- S Fermi 1
- I Big Rock Point

NEW YORK
- S Indian Point 1
- T Shoreham

OREGON
- I Trojan

PENNSYLVANIA
- T Saxton
- S Peach Bottom 1
- P Three Mile Island 2

SOUTH DAKOTA
- T Pathfinder

VERMONT
- S Vermont Yankee

WISCONSIN
- D LaCrosse
- S Kewaunee

Notes: GE Bonus, Hallam, and Piqua decommissioned reactor sites are part of the DOE Nuclear Legacy. For more information, visit DOE's Legacy Management web site at energy.gov/lm/sites/lm-sites. CVTR, Elk River, and Shippingport decommissioned reactor sites were either decommissioned before the formation of the NRC or were not licensed by the NRC.

NRC-abbreviated reactor names listed

Figure 42. Locations of NRC-Regulated Sites Undergoing Decommissioning

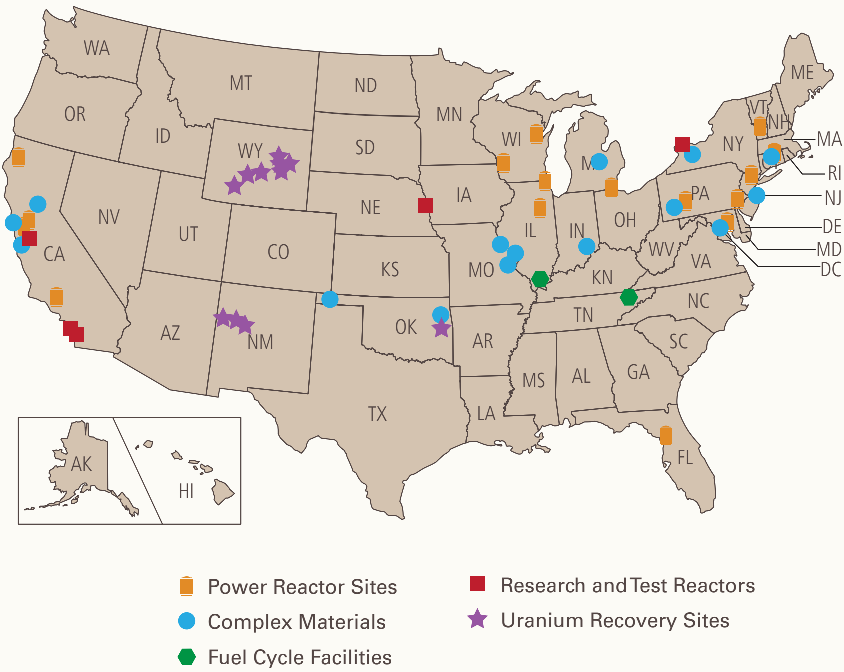


Figure 43. Facilities Undergoing Decommissioning under NRC Jurisdiction